The Eurasia Proceedings of Science, Technology, Engineering & Mathematics (EPSTEM)
ISSN: 2602-3199

The Eurasia Proceedings of Science, Technology, Engineering and Mathematics (EPSTEM), 2025

Volume 37, Pages 531-540

ICEAT 2025: International Conference on Engineering and Advanced Technology

# Experimental and Computational Evaluation of Graphene-Enhanced Fiberglass/Polyester Nanocomposites

**Zainab Abd-Ali**
University of Al-Qadisiyah

**Nabeel Almuramady**
University of Al-Qadisiyah

**Ali F. Fahem**
University of Al-Qadisiyah
Oklahoma State University

**Essam L. Esmail**
University of Al-Qadisiyah

**Abstract:** A multi-layer fiberglass-reinforced nanocomposite consisting of graphene nanoparticles, polyester resin, along fiberglass reinforcements have been fabricated using a standard templated layup approach. The composite structure is composed of three layers of graphene-reinforced polyester resin, with variable graphene concentrations of 2%, 4%, 6%, and 8% by weight, and two layers of fiberglass to support the specimen structure. The research aimed to study the physical and mechanical behavior of this novel composite material over a combination of experimental testing and numerical simulation. Tensile and compressive tests have been conducted to describe the composite's response under different mechanical loading conditions. The experimental results have shown a significant improvement in tensile strength with the incorporation of graphene nanoparticles and fiberglass into the polyester matrix. Particularly, the sample with 4% wt of graphene content exhibited a 78% increase in tensile strength compared to the unreinforced polyester resin. In contrast, the compressive strength has shown a gradual reduction with increasing graphene content, which was attributed to the inherently brittle behavior of the composite structure under compressive loading. To further validate the experimental findings and assess the overall mechanical performance, a numerical simulation was performed using the finite element analysis software ABAQUS. Numerical simulation has confirmed the trends observed in the experiments and provided insights into the stress distribution and failure mechanisms within the composite. These results have proposed that the hybrid integration of graphene nanoparticles and fiberglass into polyester matrices has offered a promising route for enhancing the tensile performance of polymer-based composites, though considerations must be made for compressive load-bearing applications.

**Keywords:** Polyester, Polymer, Fiberglass, Graphene, Nanocomposite, Numerical simulation

## Introduction

Nanotechnology is one of the most promising technologies of the current century, where the study and application of tiny objects is known as nanotechnology, and it has applications in all other branches of science, including engineering, physics, chemistry, biology, and materials science (Zhang et al., 2005, Alobaidi et al., 2023). Numerous methods, including physical, chemical, and biological processes, can manufacture nanomaterials (Almuramady et al., 2025, Alobaidi et al., 2023). They are characterized by their hardness,



- Selection and peer-review under responsibility of the Organizing Committee of the Conference

lightweight and high strength. Nanomaterials are one of the innovations of nanotechnology, which consist of two or more materials, one of which is nanosized (Rajak et al., 2019; Tiwari et al., 2020).

Nanomaterials have been widely used as nanofillers in polymers to enhance their mechanical properties, as well as thermal and electrical conductivity, when integrated into the polymer matrix to produce nanocomposites. Polymer nanocomposites (PNCs) are manufactured by dispersing nanoparticles in a polymer matrix. Polymer nanocomposites are a rapidly growing research field with multi-level applications due to their properties, which have greater tensile, electrical, thermal, and multifunctional capabilities than virgin polymers. Polyesters are one of the classes of polymers that have strong adhesive effects. Polyester resin has good thermal properties. It also has excellent electrical resistance and chemical resistance to solvents, acids, and salts. It is resistant to wear and environmental effects, and, in addition to being low cost, it is characterized by weakness and fragility. Graphene is a two-dimensional nanomaterial used to reinforce materials due to its unique properties, such as the highest recorded strength (130 GPa) and Young's modulus (1.0 TPa) ever measured.

In addition, glass fibers have long been used with polyester resin matrix due to the high specific strength, stiffness, and elastic modulus of glass fiber-reinforced polyester composites. Alawsi et al. (2025) reported that the mechanical properties of GO-GF/UPE coated composites were better than those of non-GO coated composites (Mosa et al., 2024; Jasim et al., 2022). The mechanical properties of polyester/graphene ratios were studied. When polyester is pure without any additives, the sample has lower flexibility and higher stiffness than other samples to which fillers have been added. Hadi (2022) and also Shallal and Almuramady (2025) reported that the graphene improves the stiffness property by a percentage when the stiffness of the polymer is extended at this rate due to the effect of the distribution of the nature of the homogeneous solid material. This study aims to determine the effect of graphene nanoparticles at 0,2,4,6, and 8 wt% and woven glass fibers on the mechanical properties of polyester resin.

## Experimental Work

### Materials and Methods

The polyester used in this study is unsaturated polyester resin type P-053 produced by the Turkish company Elekster. It consists of a resin and its hardener (methyl ethyl ketone). Its color is transparent, and the mixing ratio is 1:0.002 based on weight. The graphene powder, which is nanoparticles with a thickness of 6-8 nm, was produced by Skyspring Company. E-fiberglass woven was used to increase the reinforcement. Graphene was used as a reinforced nanomaterial, where graphene was weighed in the required proportions (2%, 4%, 6%, and 8%). These proportions were added to polyester; the graphene was dispersed by continuous stirring for 10 minutes. The special hardener was added and stirred with a magnetic stirrer for 5 minutes to obtain a good and homogeneous mixture. It was poured into the designated mold and left to harden at room temperature for 24 hours. After pouring all proportions and forming the nanocomposite, a new multilayer composite was formed consisting of three nanocomposite layers and two layers of woven fiberglass in order to arrange the layers of the nanoan compound and place the glassfiber- covered withpolyester for the purpose of composite layers and then shed compression and leave the classes for rigidity and fully consistently to study its mechanical properties. the samples used were manufactured according to ASTM for tensile strength D638 and compression strength ASTM D695. Three experimental setups were used to investigate the novel materials, tensile and compressive, in this work.

## Results and Discussion

### Tensile Test

Figure 1 shows the strength of fiberglass-reinforced graphene/ polyester composite at 0% by weight of graphene and the strength of polyester/graphene/glass fiber composites at 2, 4, 6, and 8% wt by weight of graphene. There is a significant increase in strength from 25MPa at 0wt% to 40.5MPa at 2wt%, and continues to 44.5MPa at 4%. After that, the strength decreases, reaching 36.5MPa at 6wt% and 31.5MPa at 8wt%. The stress-strain curves shown in Figure 2 clearly show that the compound behaves like a brittle. The differences in values at the 6wt% and 8wt% weight ratio result from weak interfacial bonding between the matrix and the nanofillers due to the presence of agglomerates, which will form a defect area where fracture begins.

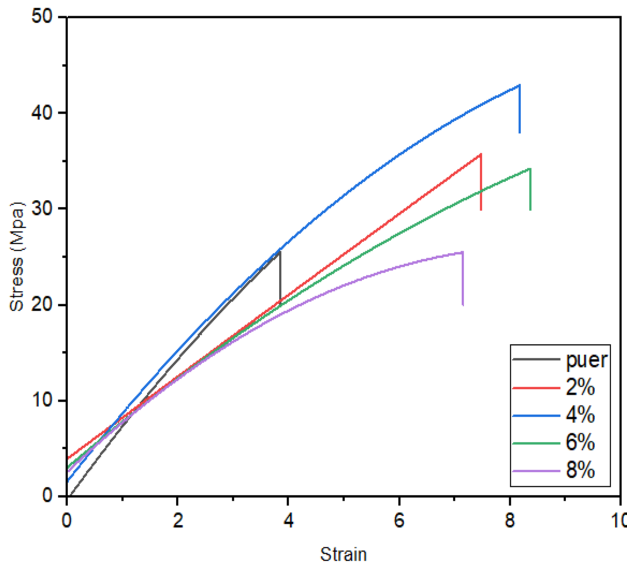



Figure 1. Stress-strain curves for tensile test

**Compression Test**

Figure 2 shows the relationship between compressive strength and graphene percentages. According to the results obtained, it was found that the strength recorded the highest value at 0% of graphene weight, where it was 166.6 MPa. However, when adding different graphene percentages (2, 4, 6, and 8wt%), the strength began to decrease, respectively (141.78 MPa, 128.76 MPa, 105.6 MPa, and 84.25 MPa). The reason for these decreases is due to the agglomeration of graphene, as well as the brittle behavior of the nanocomposite. Failure occurred first in the nanocomposite.

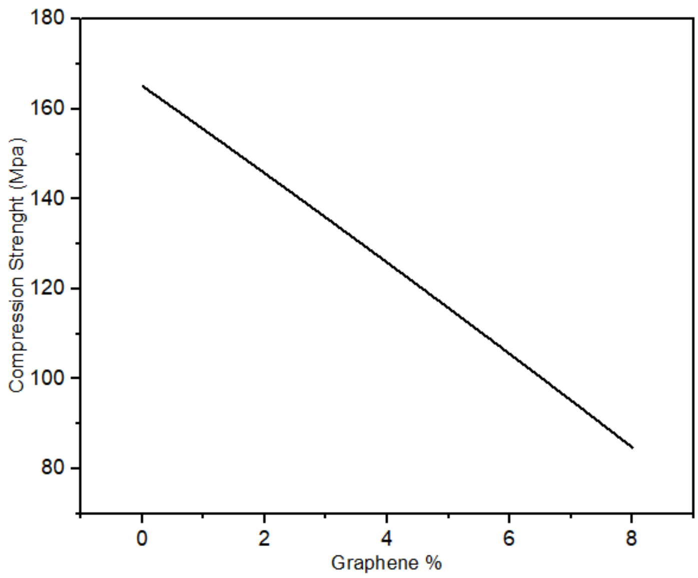



Figure 2. Compression results of fiberglass-reinforced graphene/polyester composite

## Numerical Investigation

Today, numerical modeling is a crucial simulation tool in different industries, including the automotive, aerospace, and civil engineering sectors. Engineers can design products and optimize manufacturing processes with the help of the finite element (FE) method, a popular numerical tool. FEM has been successfully used for 30 years to tackle various problems. The development of digital computers, which allow engineers to solve complicated equation systems quickly and effectively, contributed to the popularity of the finite element method. Comparing finite element results to analytical solutions or experimental data is a standard method for confirming their accuracy. FEM can handle complex structures without requiring significant modifications or incorporating complex relationships, in contrast to conventional numerical methods. FEM tools like ABAQUS have extensively been used to research elastomer-like materials. In this study, the work was simulated by ABAQUS for both tensile and Compression Tests.

**Tensile Test**

Tensile tested using Abaqus. The model applies the cathedral coordinates with X, Y, and Z representing thumbnails, width, and longitude. The sample is installed from the bottom in all directions while the top portion was pulmonated in all directions except the longitudinal direction, where it was unrestricted and its free movement was in response to the applicable pregnancy. Figure 3 CAD illustrates a sample.

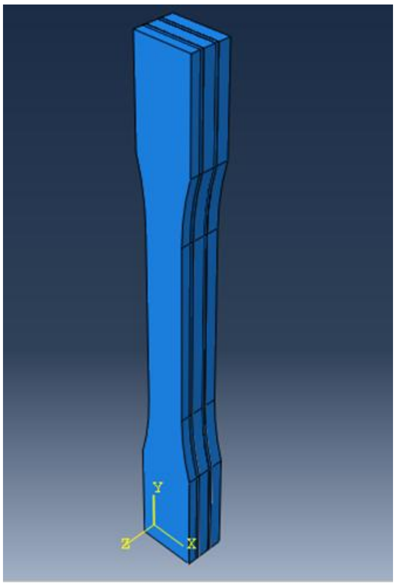



Figure 3. CAD illustrates a sample.

This examination has been accredited only for the strain gauge to examine stress. Figure 4 observes the mesh used in the simulation; it was applied to all specimens. Which are 41250 hexahedral elements of type CPS4R with a global size of 500 µm.

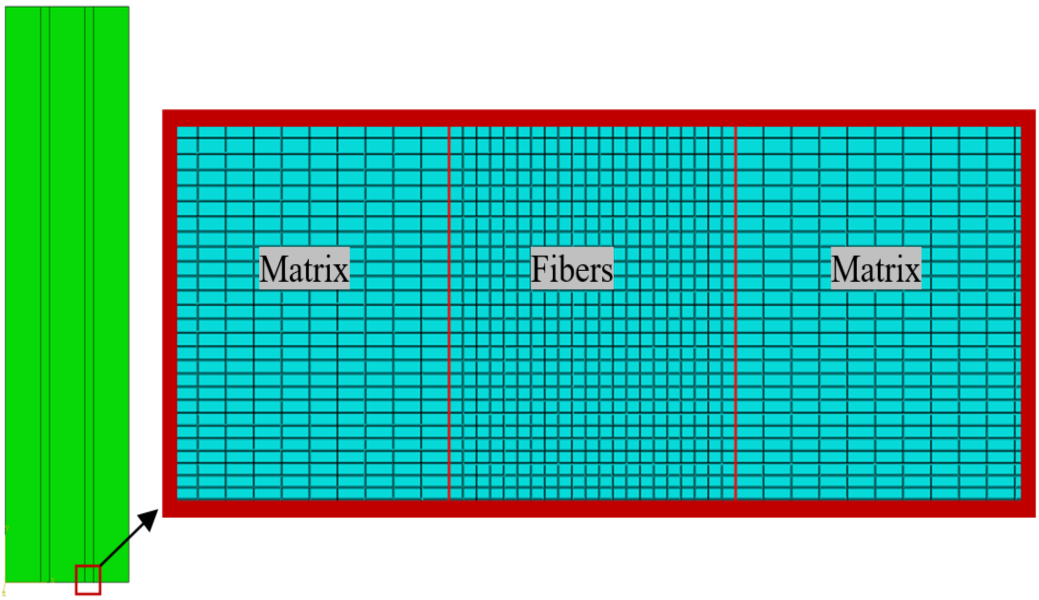



Figure 4. Mesh of tensile specimen.

The fiberglass-reinforced graphene/ polyester composite in Figure 5 shows at 0, 2, 4, 6, and 8wt%, which appears in the experimental results as shown in Table 1.

Table 1. Ultimate tensile strength (Mpa)

| Graphene% | Experimental Results (Mpa) | Numerical Results(Mpa) | Deviation% |
|---|---|---|---|
| 0 | 25 | 56.91 | 127.64% |
| 2 | 40.5 | 134.5 | 232% |
| 4 | 44.5 | 146.6 | 229.2% |
| 6 | 36.5 | 150 | 310.9% |
| 8 | 31.5 | 169.6 | 438.4% |

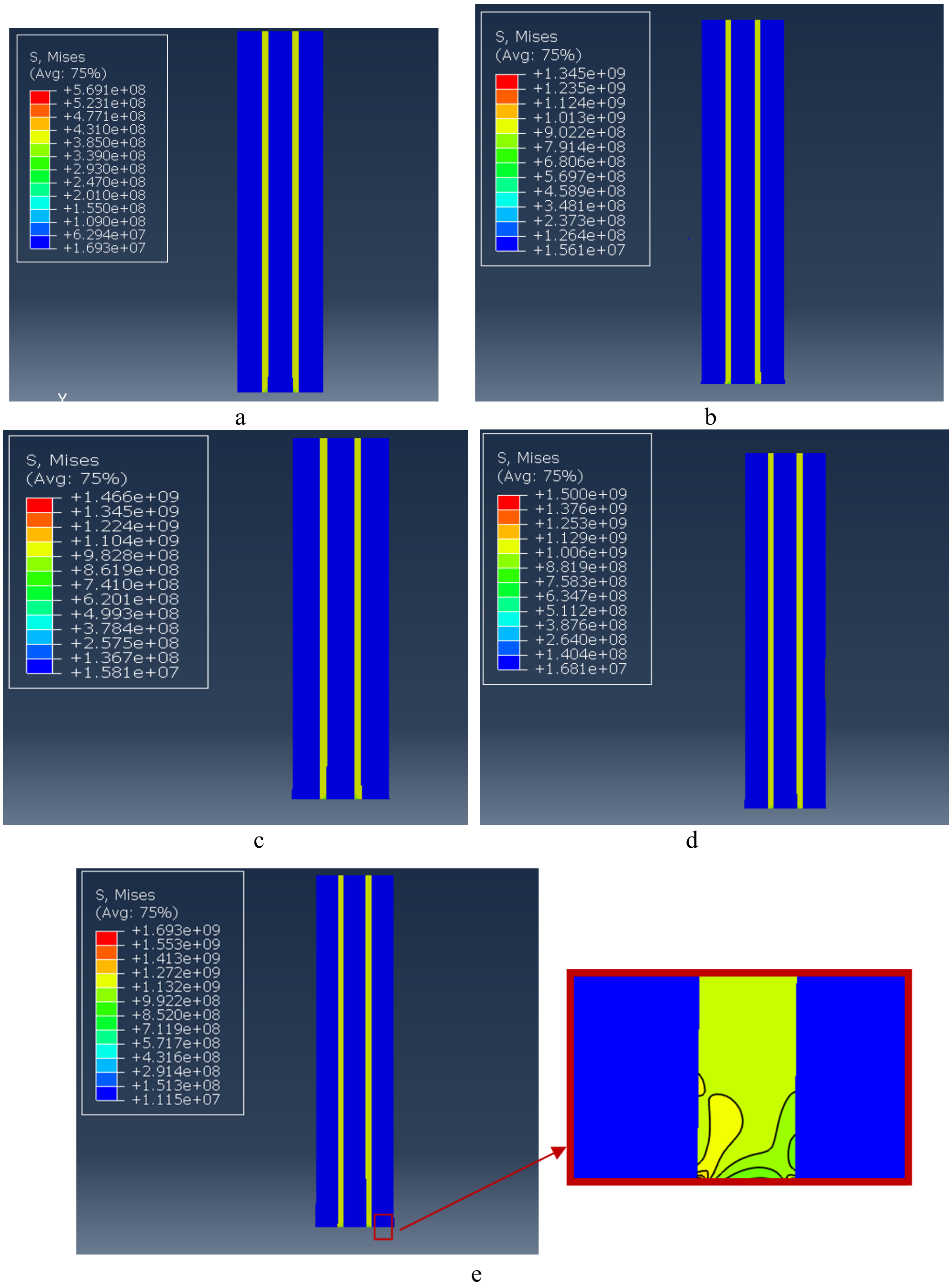



Figure 5. Stress distribution during subjecting ultimate load at (a)0%,(b)2%,(c)4%,(d)6%,(e)8%.

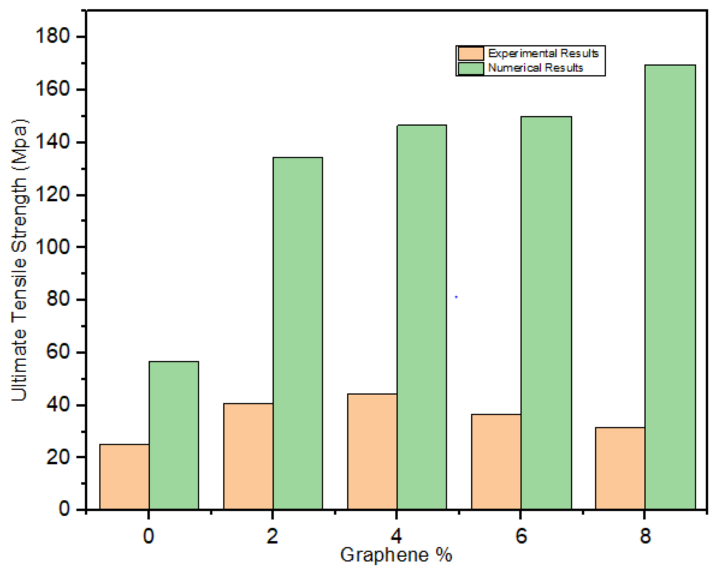



Figure 6. Results of tensile strength experimentally and numerically.

## Compression Test

ABAQUS has been used to hold simulators for limited elements on fiberglass-reinforced graphene/ polyester composite samples, which has solved difficult problems in both linear and nonlinear behavior. Tested pressure testing samples in ABAQUS using ASTM D695, which matches for samples used in experiments. To repeat the real pressure test, the borders are applied and loading conditions in an equivalent experience where the eye was drawn as a five-layer (three layers of the nanocomposite and two layers of fiberglass), and properties were entered separately. The bottom is installed for samples in all directions, while the top pose is connected in all directions except the longitudinal trend, where it was unregulated, and its free mobility is responsible for pregnancy. It was currently being held at three different regions (the beginning of the test, the center, and when failure). This was based on the experimental data to ensure the form of the form. Figure 7 shows the CAD of specimens.

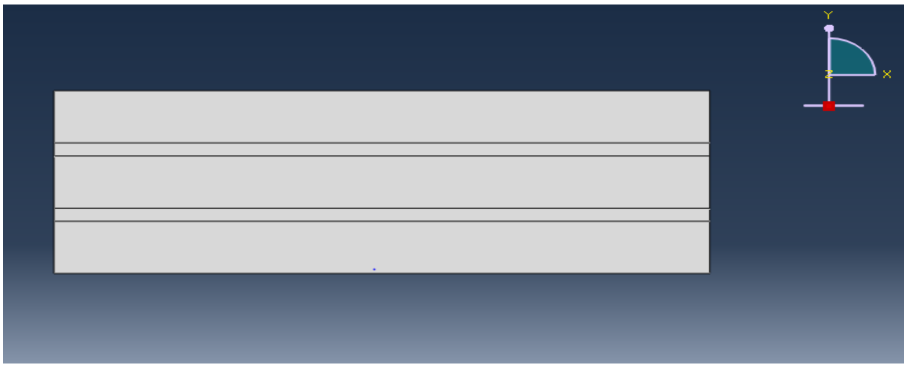


Figure 7. The CAD of specimens.

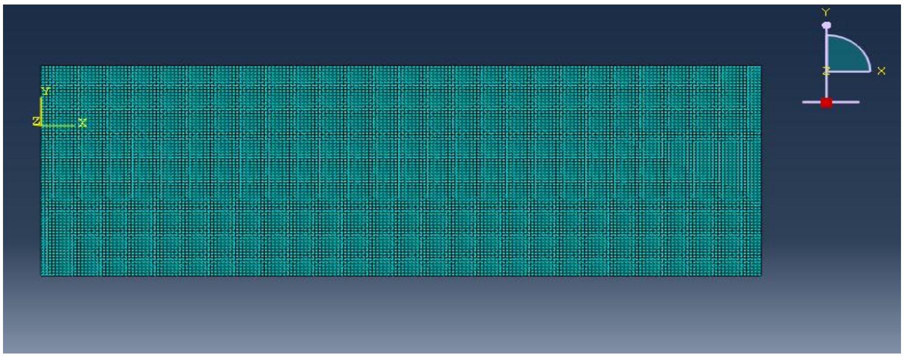
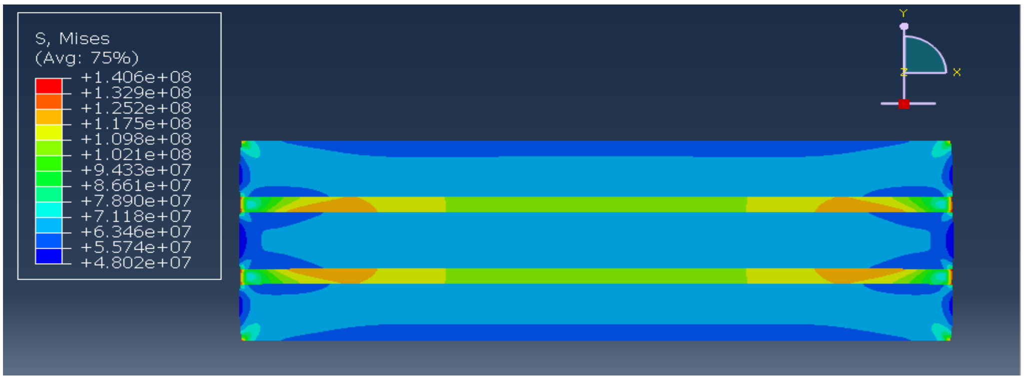


Figure 8. Mesh of compression specimen.

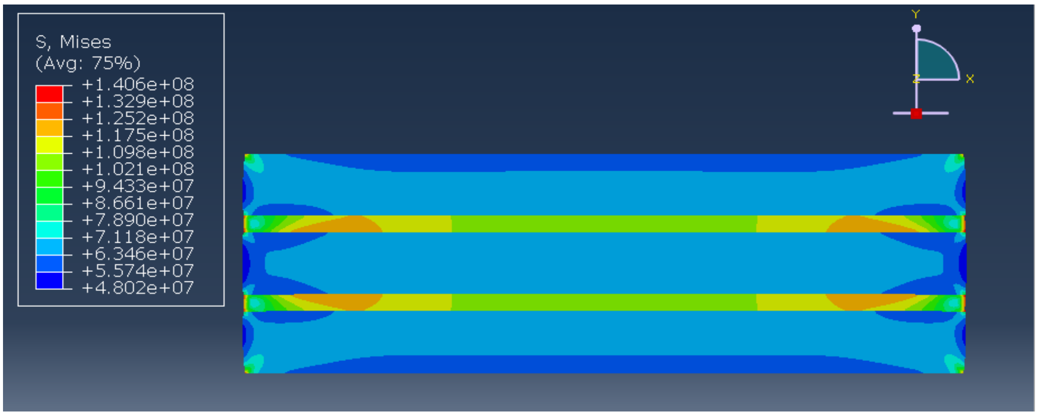
Figure 8 is the network used in simulations, which was applied in all samples. It is 25365 cps4r-type surfaces with a global size of 0.0002. For fiberglass-reinforced graphene/ polyester at 0,2,4,6 and 8wt% graphene, the numerical results show a deviation from the experimental result of about 15.5%,15.5%,2.4%,27.7%, and 88%. The numerical results of it observed in Figure 9 and Table 2.

Table 2. Compression strength (Mpa)

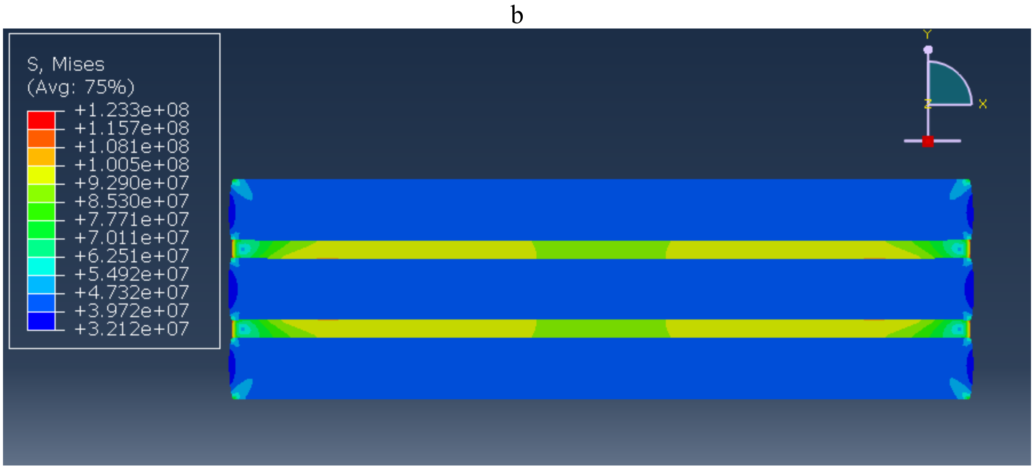
| Graphene% | Experimental Results (Mpa) | Numerical Results (Mpa) | Deviation% |
|---|---|---|---|
| 0 | 166.55 | 140.6 | **15.5%** |
| 2 | 141.78 | 119.7 | **15.5%** |
| 4 | 126.362 | 123.3 | **2.4%** |
| 6 | 112.603 | 143.8 | **27.7%** |
| 8 | 85.808 | 161.4 | **88.0%** |



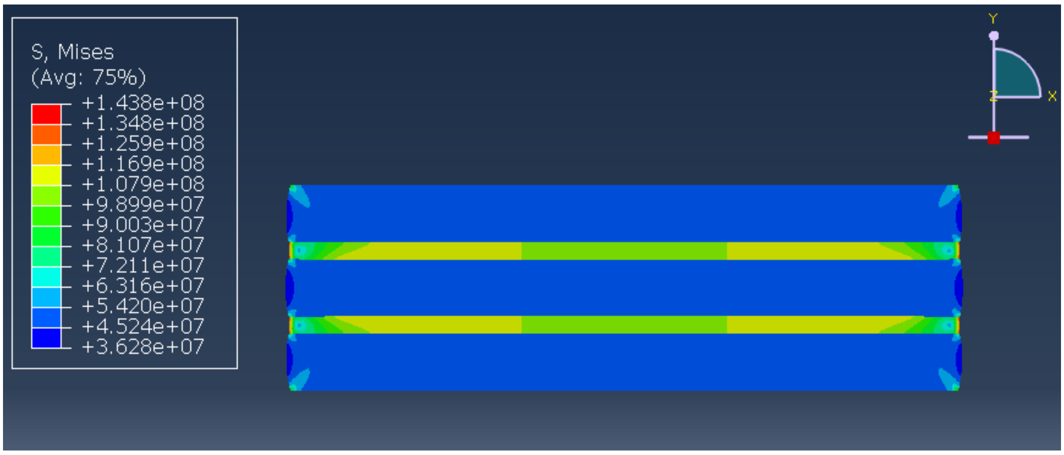

a



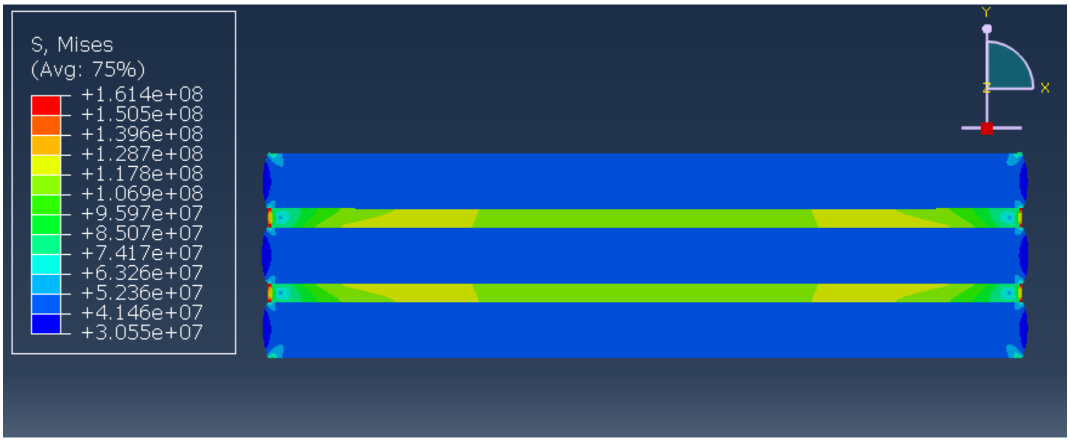

b




c




d




e

Figure 9. Numerical Results of compression strength at (a) 0%, (b)2%, (c)4%, (d)6%, (e)8%.

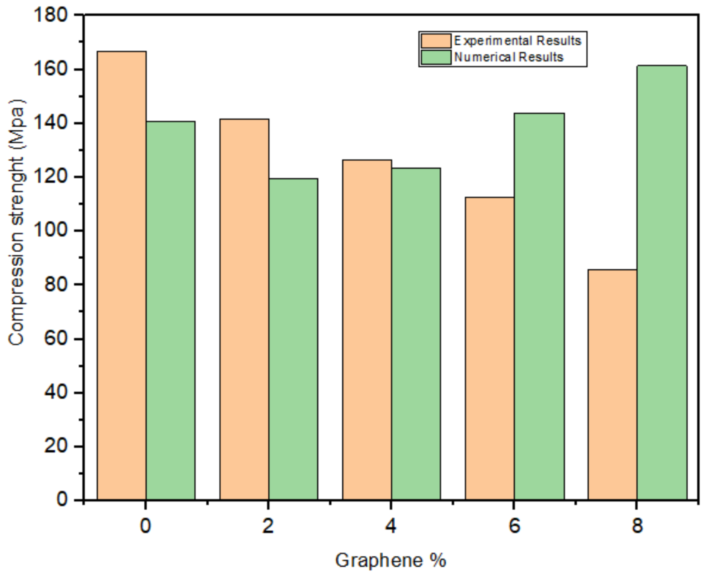



Figure 10. Results of compression strength experimentally and numerically

From the figures above, it can be seen that the fiberglass, represented by the red areas, are the stress distribution area, where the stress is initially concentrated in the middle of the fiberglass, represented by the red color, and then gradually begins to move to the edges of the sample, as is evident in the transition of colors from red to yellow and then green, gradually until the stress is concentrated at the edges of the sample, where failure begins. This is similar to the experimental results. Exposure to the highest pressure is indicated in the glass fibers area by the red balloon, which is concentrated at the edges of the sample, and after that, the pressure gradually decreases towards the nanocomposite area, as is evident in the transition from red to blue. Figure 10 shows the results of the compression strength experimentally and numerically.

## Conclusion

In this study, the effect of incorporating graphene reinforced with glass fibers into polyester resin matrices at different percentages on the mechanical properties of the resulting composite has been investigated. Experimental results demonstrated that both compression and tensile strengths have improved compared with the base sample (0% graphene), with the highest enhancement which has observed at a graphene content of 4%. However, a decline in these properties was noted at this concentration, with the lowest values recorded at 8% graphene. On the other hand, compressive strength has exhibited a decreasing trend with increasing graphene percentages. These reductions are attributed to poor interfacial bonding between the polyester matrix and nanoparticles at higher concentrations, leading to particle agglomeration. Such agglomerates act as stress concentrators, initiating early failure under compressive loading. Generally, these findings have indicated that while moderate additions of graphene can improve certain mechanical properties, excessive graphene content might have a detrimental effect, mostly on the compressive strength. Hence, optimal graphene loading is critical for achieving balanced mechanical performance in graphene-reinforced polymer composites.

## Scientific Ethics Declaration

* The authors declares that the scientific ethical and legal responsibility of this article published in EPSTEM journal belongs to the authors

## Conflict of Interest

* The authors declare that they have no conflicts of interest

## Funding

* The authors received no financial support for the research, authorship, and publication of this article.

## Acknowledgments

* The authors would like to thank the International Conference on Engineering and Advanced Educational Technology (ICEAT).

## References

Abd E-Aty, M., & Ghazal, H. (2023). Nanotechnology and application of nano titanium dioxide, nano zinc oxide, and nano copper oxide on textile for high performance. *Egyptian Journal of Chemistry*, *66*(3), 309–322.

Alawsi, M. H. M., et al. (2025). Experimental and numerical study of ballistic impact performance on steel plate structures. *Al-Qadisiyah Journal for Engineering Sciences*, *29*(2), 177–183.

Alobaidi, H. A., & Almuramady, N. (2023). A review of fatigue analysis and mechanical approaches of rubber composites. *AIP Conference Proceedings* (Vol. 2787, No. 1). AIP Publishing.

Alobaidi, H. A., Almuramady, N., & Ali, M. M. (2023). Influence of adding epoxy on fatigue strength of natural rubber. *AIP Conference Proceedings* (Vol. 2787, No. 1). AIP Publishing.

Almuramady, N., Fahem, A. F., Al-Jothery, H. K., & Esmail, E. L. (2025). Influence of combined carbon-epoxy on the fatigue life of elastomer materials. *Al-Qadisiyah Journal for Engineering Sciences*, *18*(1), 15–21.

Groover, M. P. (2019). *Fundamentals of modern manufacturing materials*. Wiley.

Hadi, R. S. (2022). Study the mechanical properties of epoxy resin reinforcement by ziziphus spina-christi powder. *Al-Qadisiyah Journal for Engineering Sciences*, *15*(1), 12–18.

Jasim, A. M., & Mahmood, I. A. (2022). Flexural and fatigue behaviour of natural fibrous reinforced polymeric composite materials. *Al-Qadisiyah Journal for Engineering Sciences*, *15*(2), 86–92.

Mosa, M. H., Fahem, A., & Guthai, A. T. (2024). Experimental investigation of perforated multi-layered composite armor subjected to ballistic impact. *Al-Qadisiyah Journal for Engineering Sciences*, *17*(1), 16–21.

Mosa, M. H., & Hamza, M. N. (2022a). Evaluating the performance of a unique design of biomimetic armor. *AIP Conference Proceedings* (Vol. 2651, No. 1). AIP Publishing.

Mosa, M. H., & Hamzah, M. N. (2022b). Perforation resistance of four different thicknesses of AISI-1080 steel plates subjected to ballistic impact. *International Middle Eastern Simulation and Modelling Conference*, pp. 276–281.

Oudah, A. A., Hassan, M. A., & Almuramady, N. (2023). Materials manufacturing processes: Feature and trends. *AIP Conference Proceedings* (Vol. 2787, No. 1). AIP Publishing.

Qian, L., & Hinestroza, J. P. (2004). Application of nanotechnology for high performance textiles. *Journal of Textile and Apparel, Technology and Management*, *4*(1), 1–7.

Rajak, D. K., Pagar, D. D., Kumar, R., & Pruncu, C. I. (2019). Recent progress of reinforcement materials: A comprehensive overview of composite materials. *Journal of Materials Research and Technology*, *8*(6), 6354–6374.

Saharudin, M. S., Atif, R., & Inam, F. (2017). Effect of short-term water exposure on the mechanical properties of halloysite nanotube-multi layer graphene reinforced polyester nanocomposites. *Polymers*, *9*(1), 27.

Shallal, M. A., & Almuramady, N. (2025). Effect of dissociation on the frictional contact of micro-copper pair. *AIP Conference Proceedings* (Vol. 3211, No. 1, p. 040006). AIP Publishing LLC.

Tiwari, S. K., Sahoo, S., Wang, N., & Huczko, A. (2020). Graphene research and their outputs: Status and prospect. *Journal of Science: Advanced Materials and Devices*, *5*(1), 10–29.

Zhang, Y. H., Ruan, W. J., Li, Z. Y., Wu, Y., & Zheng, J. Y. (2005). DFT study on the influence of meso-phenyl substitution on the geometric, electronic structure and vibrational spectra of free base porphyrin. *Chemical Physics*, *315*(1-2), 201–213.

## Author(s) Information

**Zainab Abd-Ali**
University of Al-Qadisiah, College of Engineering, Al-Diwaniyah, Iraq

**Nabeel Almuramady**
University of Al-Qadisiah, College Of Engineering, Al-Diwaniyah, Iraq
Contact e-mail: *nabeel.almuramady@qu.edu.iq*

**Ali F. Fahem**
University of Al-Qadisiah, College Of Engineering, Al-Diwaniyah, Iraq.
Oklahoma State University, College of Engineering, Architecture and Technology, School of Materials Science and Engineering, Tulsa, OK, 74106, USA

**Essam L. Esmail**
University of Al-Qadisiah, College Of Engineering, , Al-Diwaniyah, Iraq

**To cite this article:**

Abd-Ali, Z., Almuramady, N., Fahem, A. F., & Esmail, E. L. (2025) Experimental and computational evaluation of graphene-enhanced fiberglass/polyester nanocomposites. *The Eurasia Proceedings of Science, Technology, Engineering and Mathematics (EPSTEM), 37,* 531- 540.